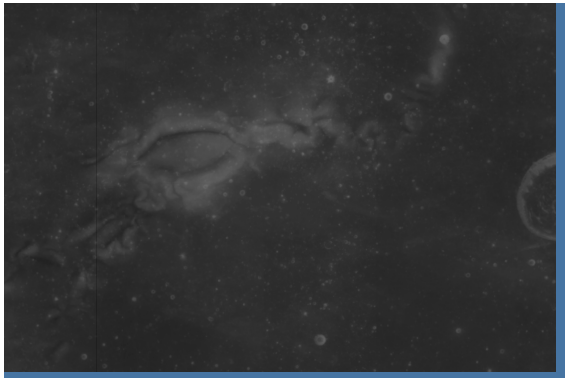

Regional Variations in FUV Lunar Signatures: Swirls

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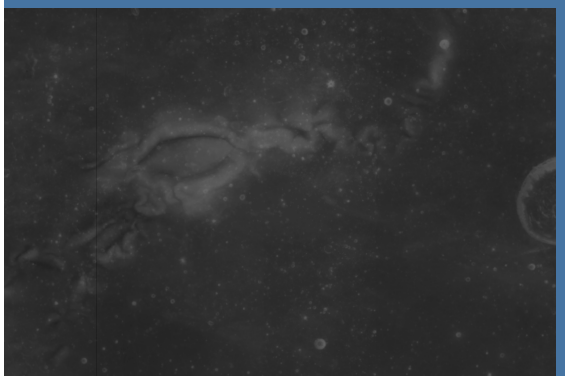
Swirls: a quick overview

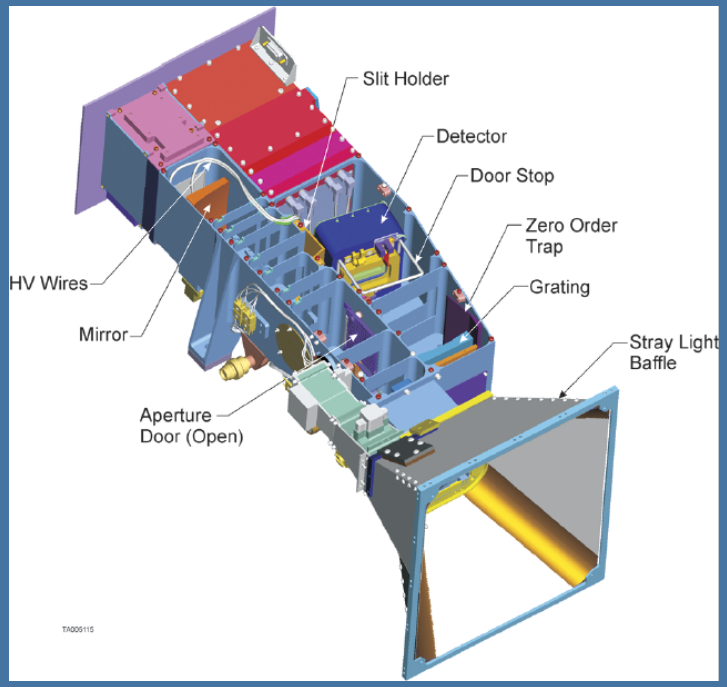
- Swirls are associated with areas of magnetized crust
- Swirls exhibit spectral characteristics (VNIR) similar to immature material
- Possible causes:
  - Stand-off of solar wind (e.g. Glotch et al., 2015)
    - Inhibiting nanophase iron production (except via micrometeoroid bombardment)
    - Could also enhance weathering in surrounding regions (Kramer et al., 2011)
  - Dust transport caused by electric fields (e.g. Garrick-Bethell et al., 2011)
    - Accumulating fine-grained feldspathic particles in these regions

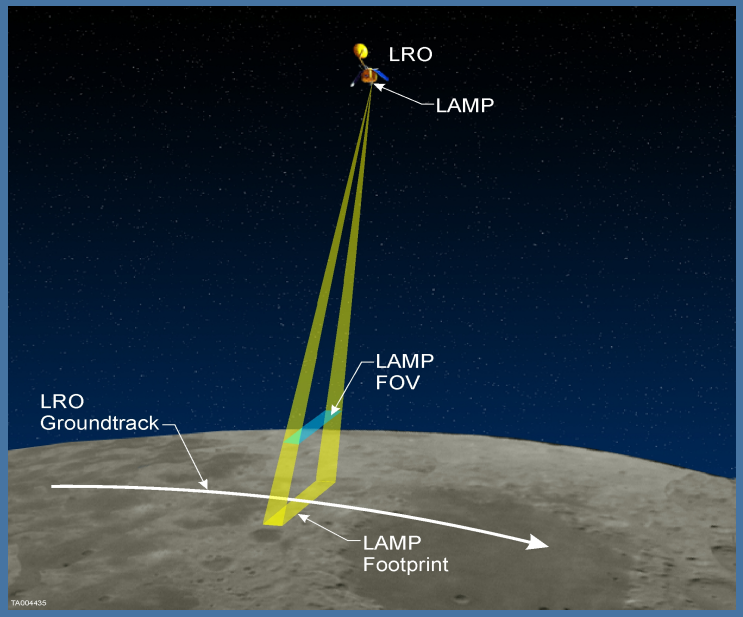


LRO LAMP

Lyman Alpha Mapping Project

LAMP:
FUV Spectrograph
Mass: 6.08 kg
Power: 4.8 W
λ Range: 57-196 nm
FOV: 0.3°×6.0°
Filled-Slit λ Range: <4 nm



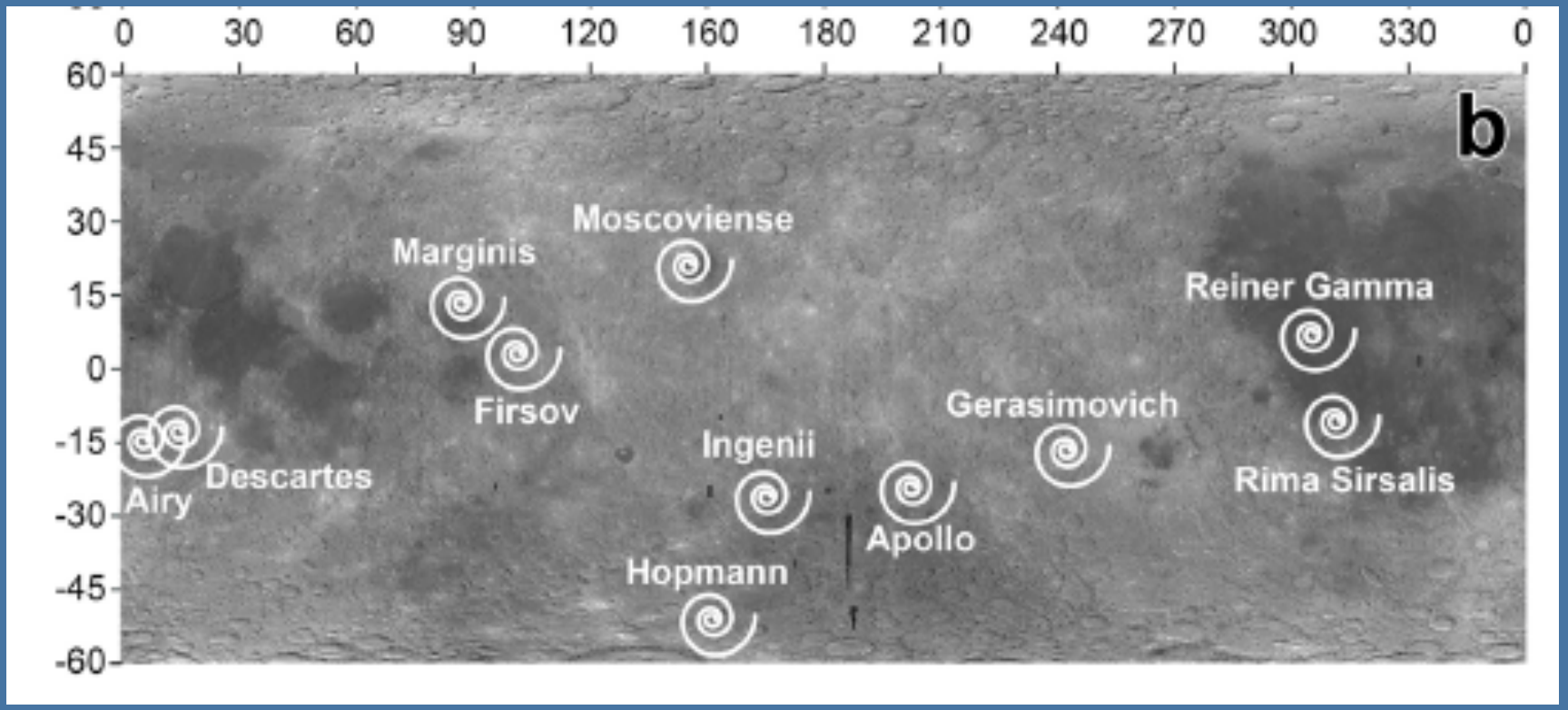


FUV: ~100-200 nm
NUV: ~200-350 nm

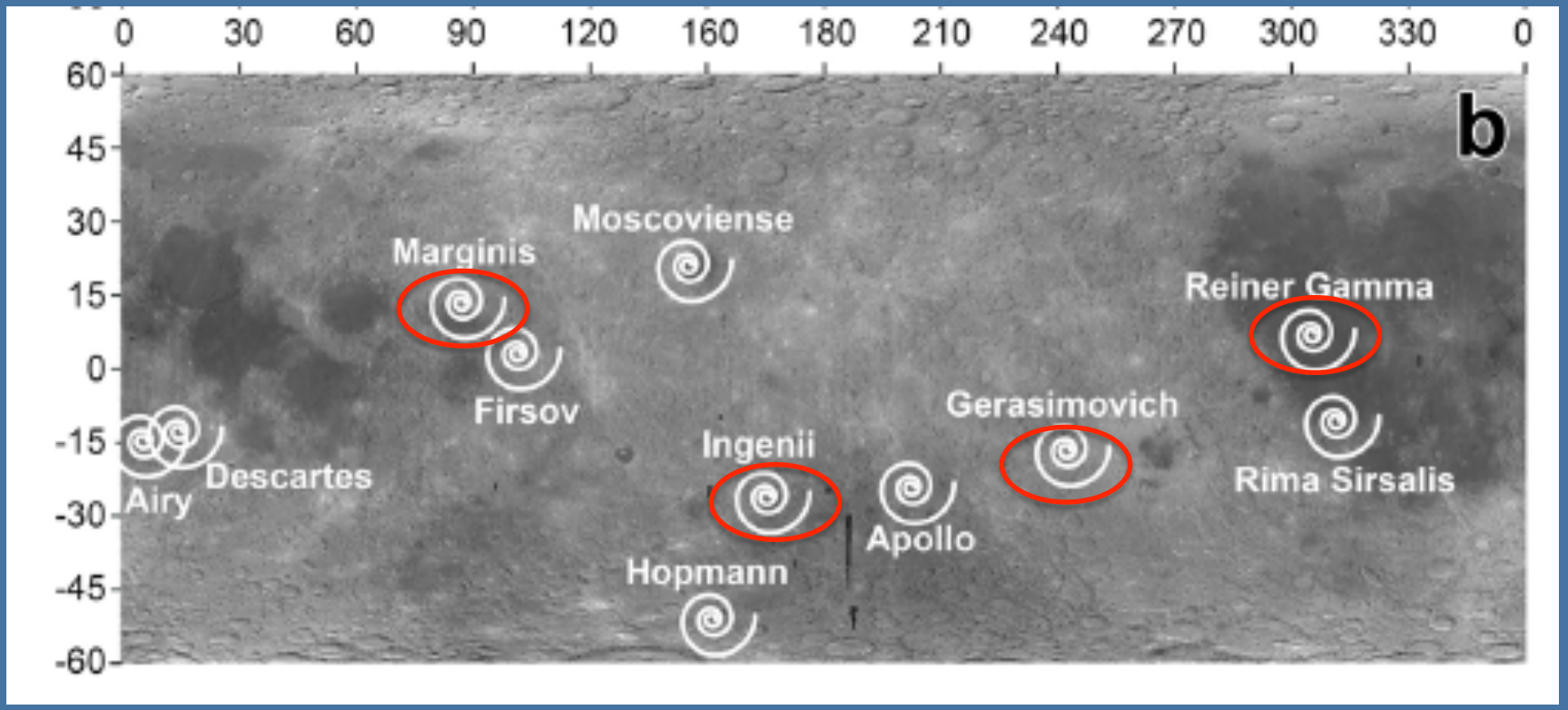
FUV: Surface scattering regime

$$R \propto \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2}$$

Swirls



from Kramer et al., 2011

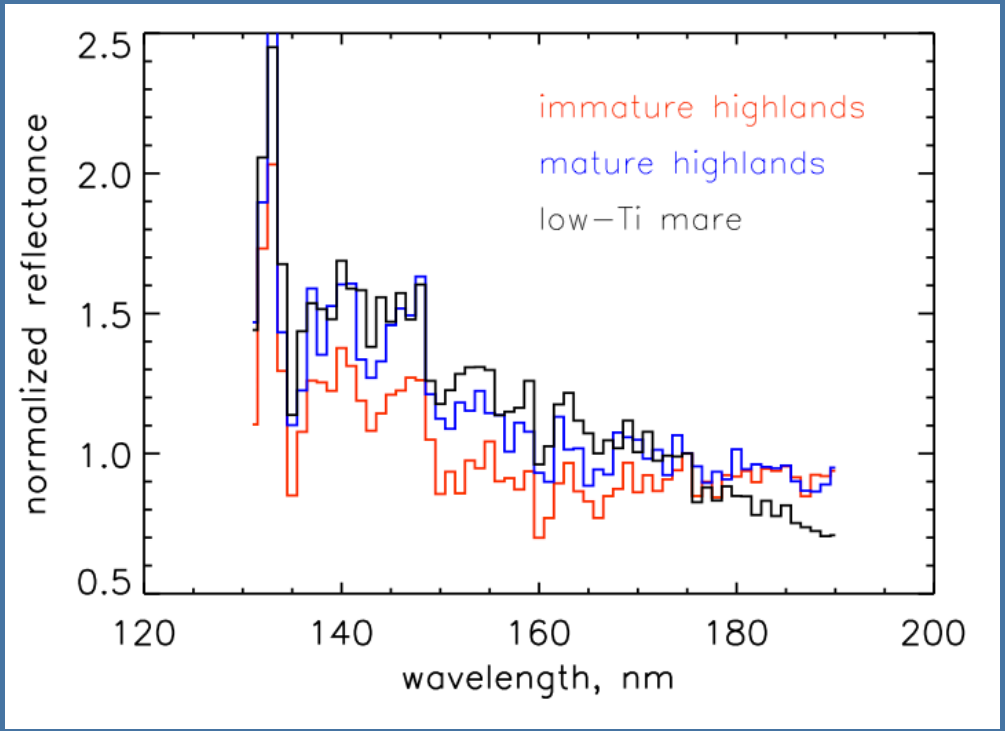


Here we focus on Reiner & Gerasimovich

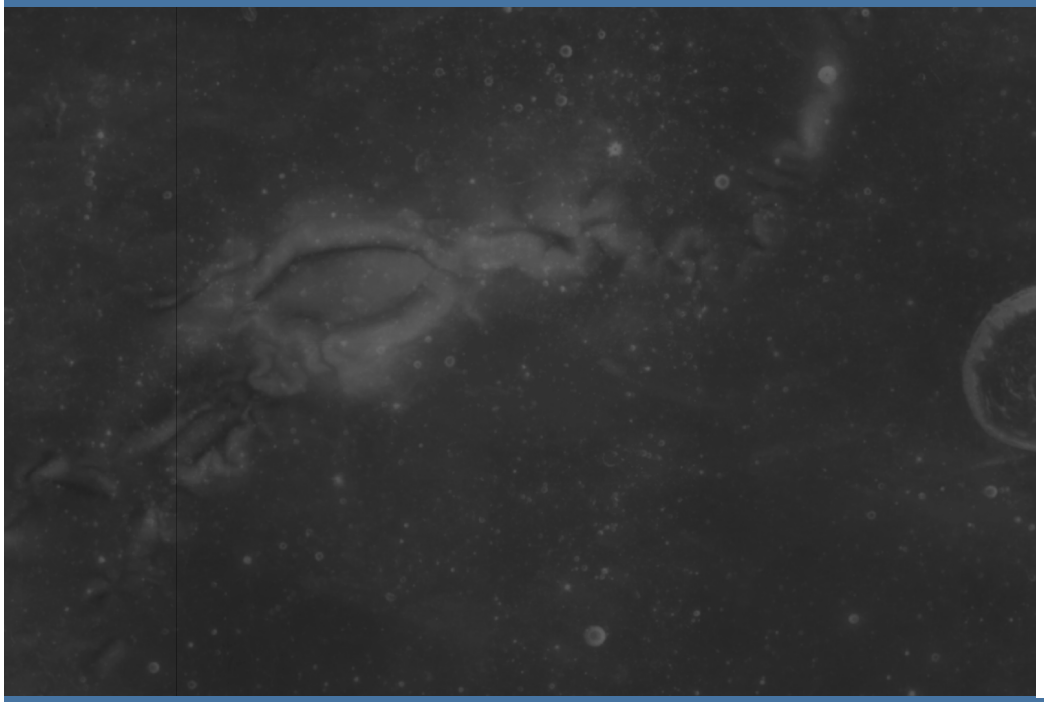
from Kramer et al., 2011

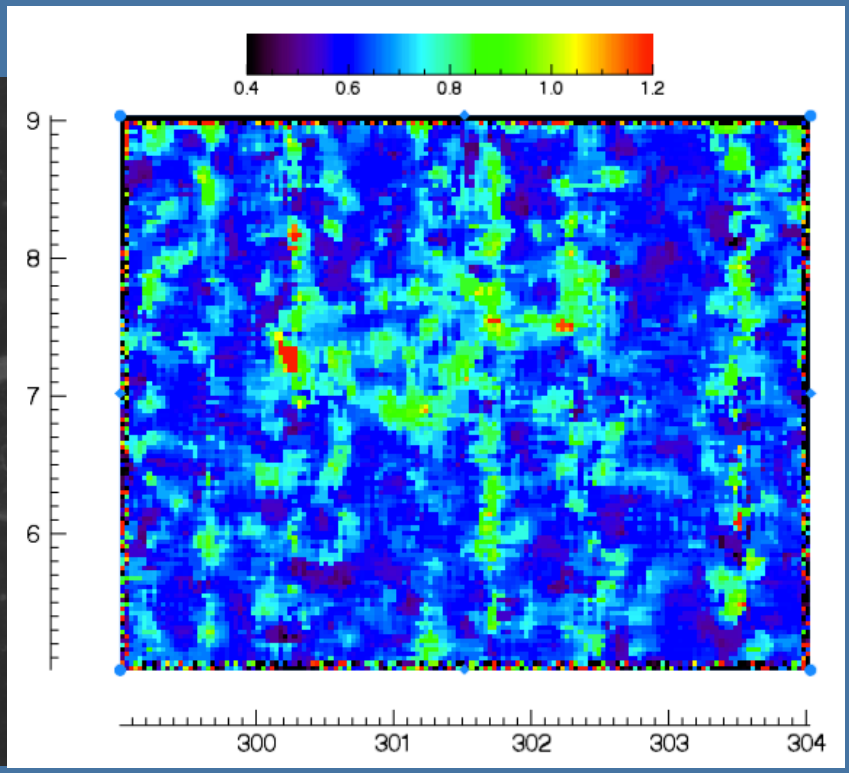
UV ratio images

- For these ratio (180/150 nm) images, generally
  - Highlands: higher ratio values (red, less blue)
  - Maria: lower ratio values (blue)
  - Weathered regions: lower ratio values
  - Less-weathered regions: higher ratio values (less blue)



Reiner Gamma

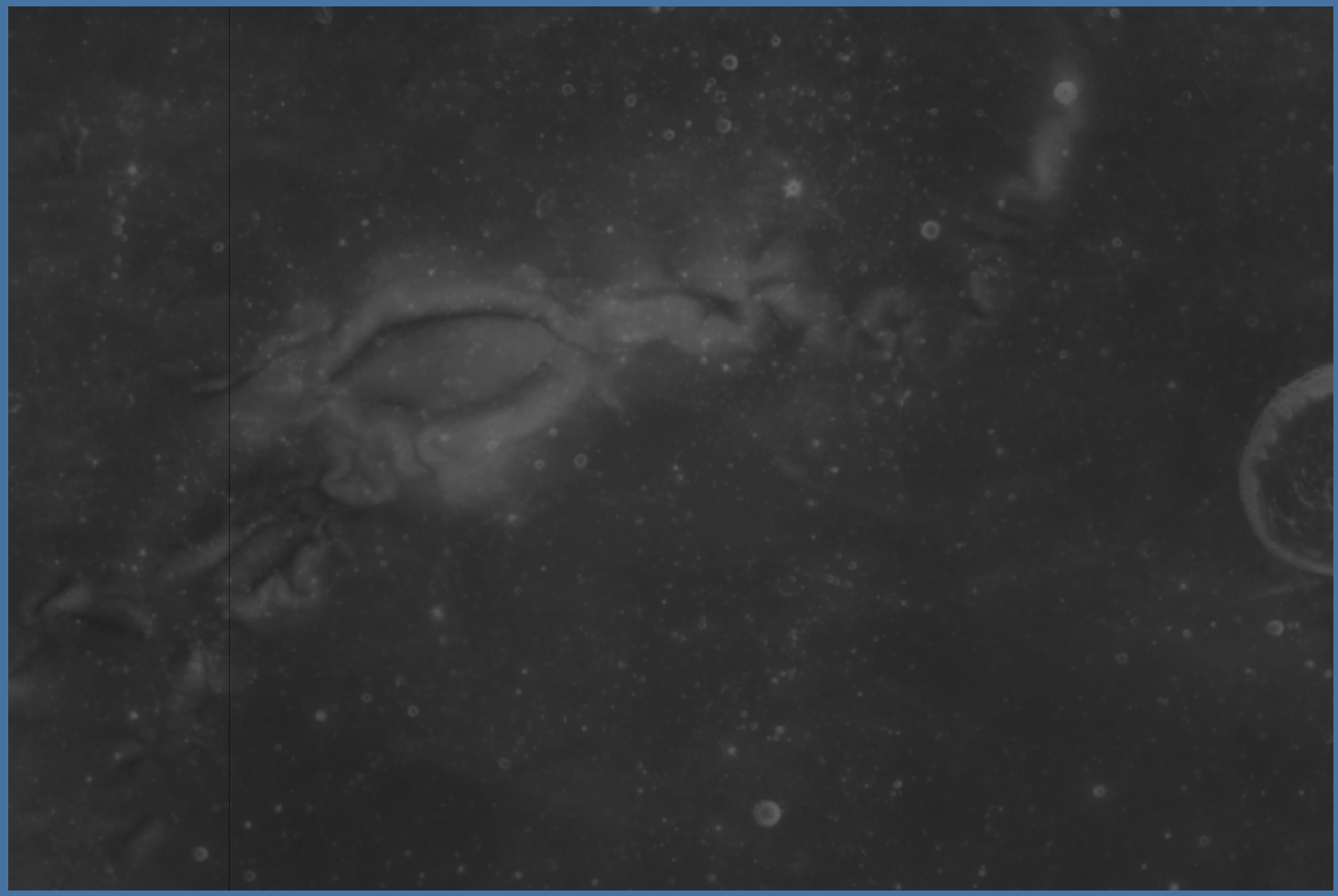




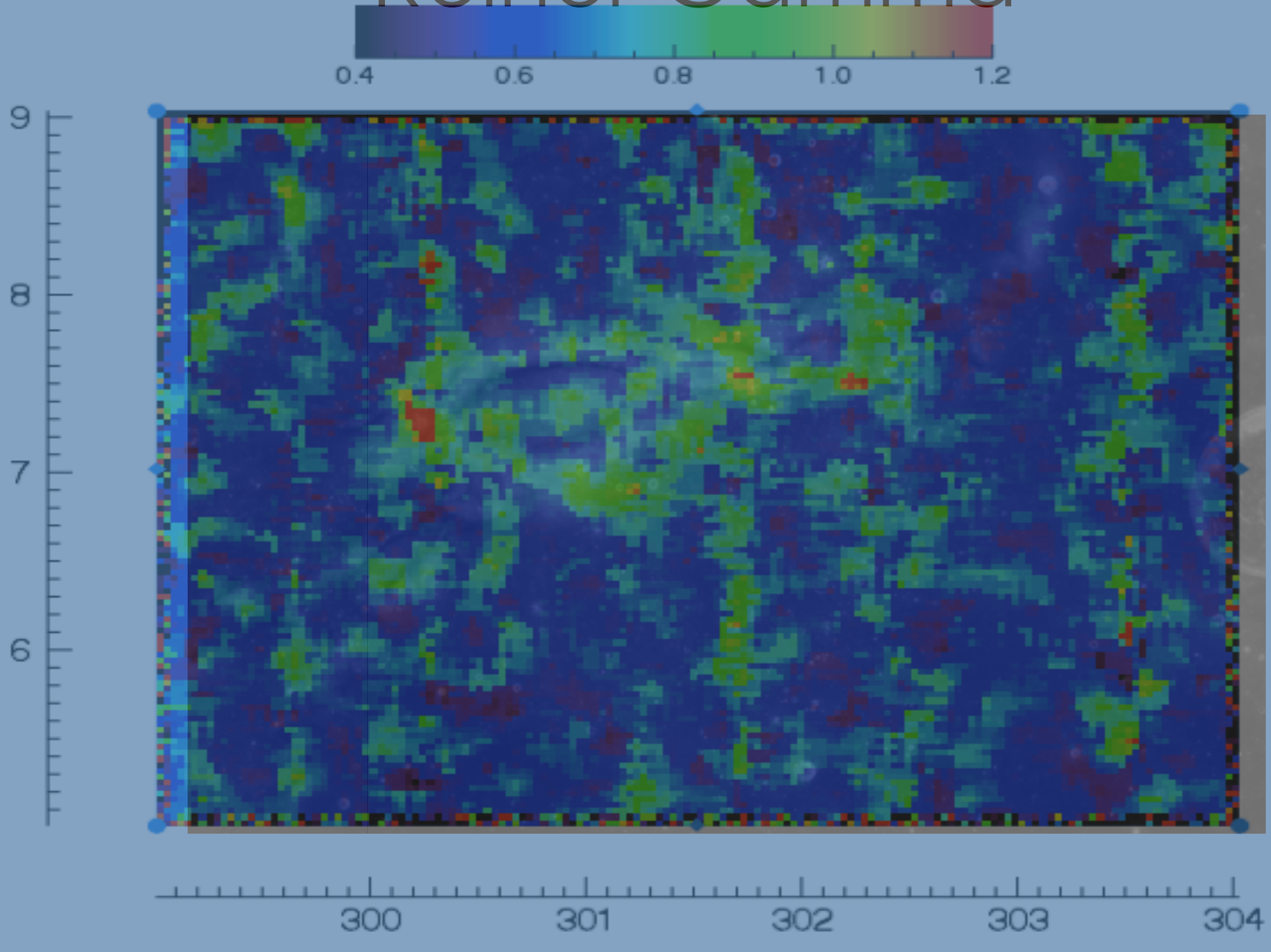
Ratio (~180-190 nm/150 nm); with phase correction

summing 22 months of data with beta<70°

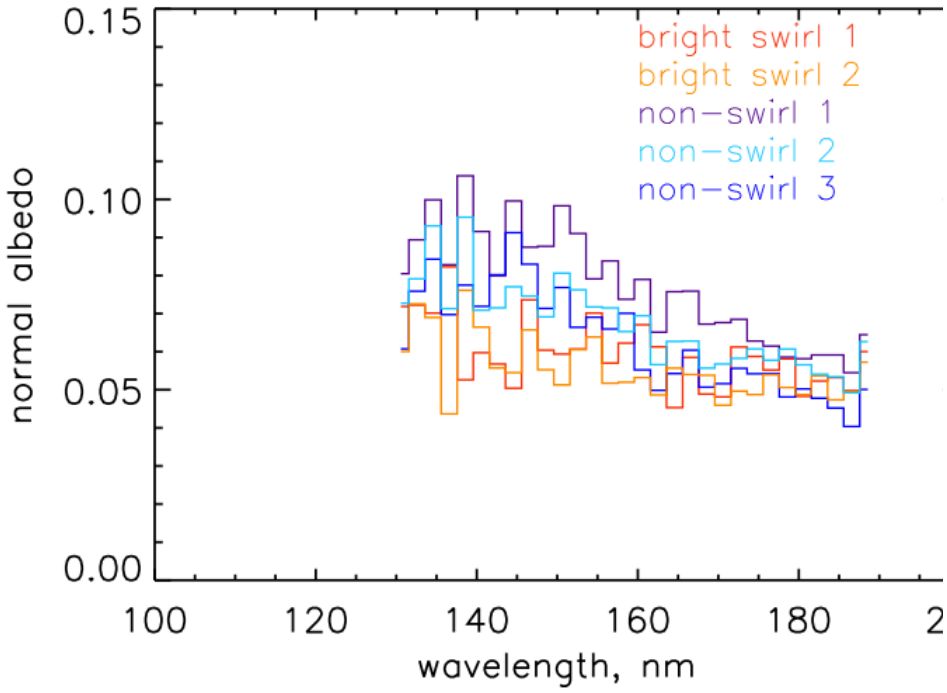
Reiner Gamma

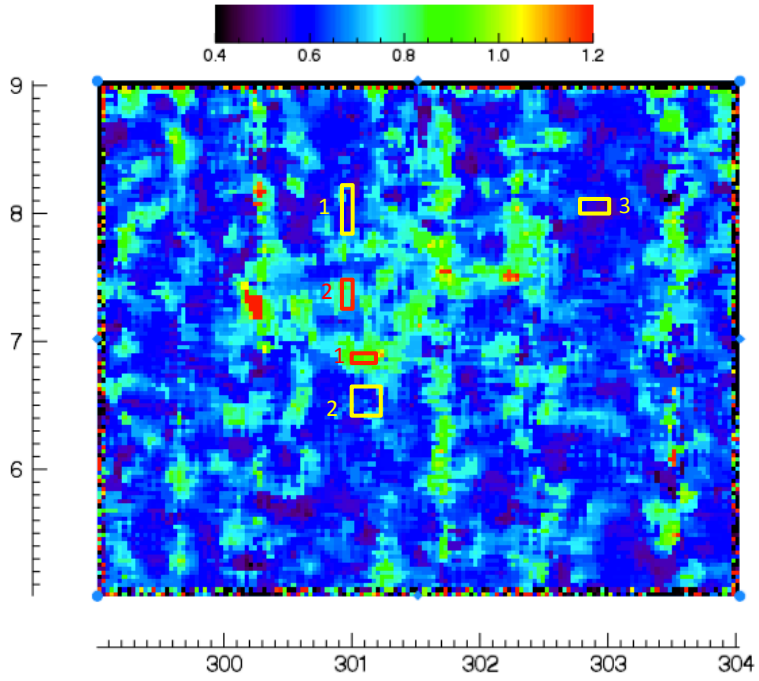


Reiner Gamma



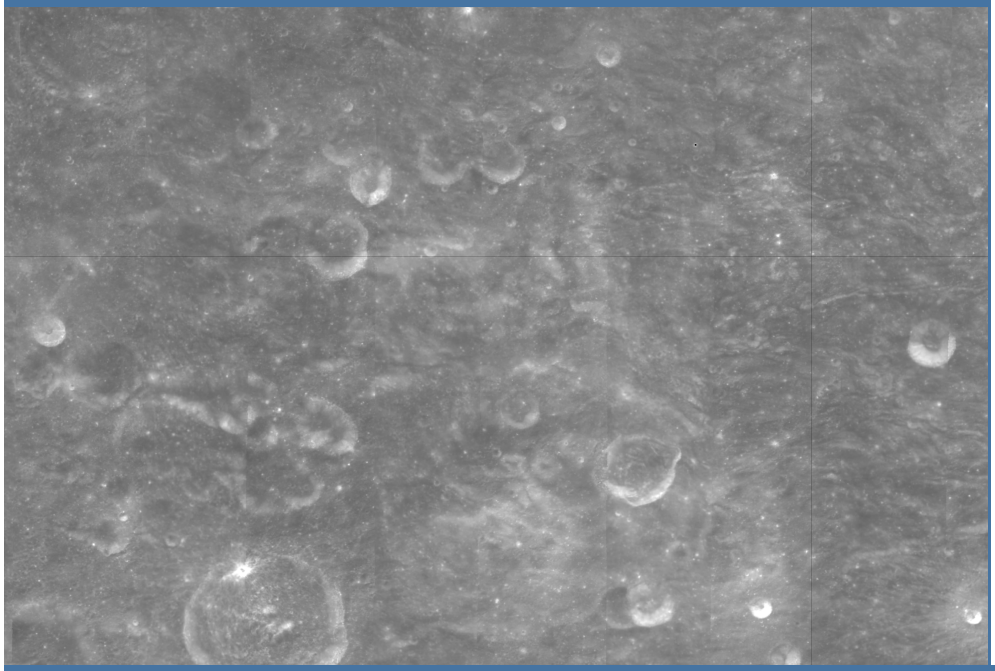
Reiner Gamma

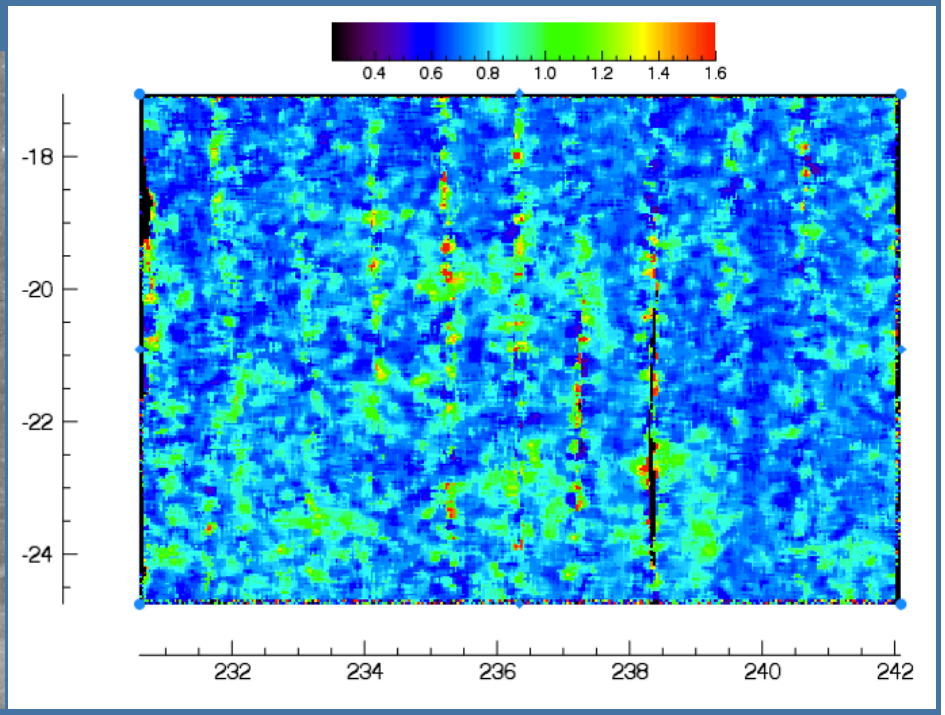




The visibly-bright swirl region is less blue in FUV than surrounding terrain

Gerasimovich swirl

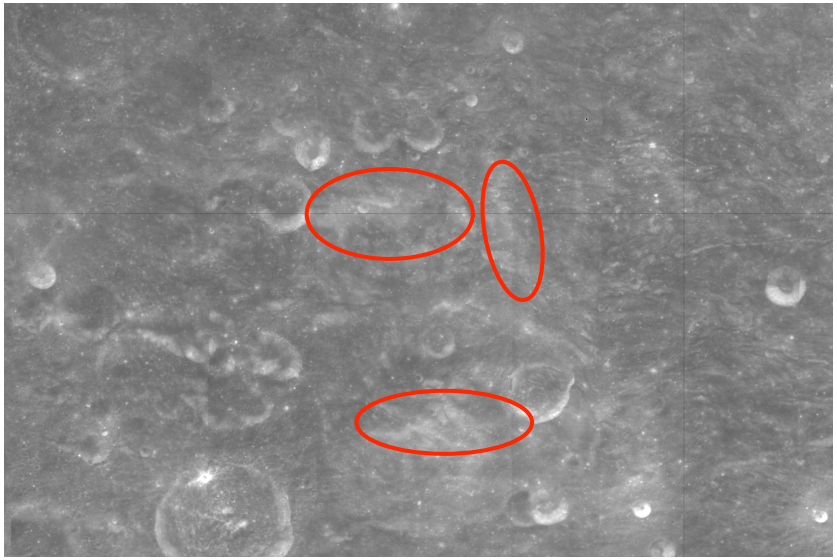


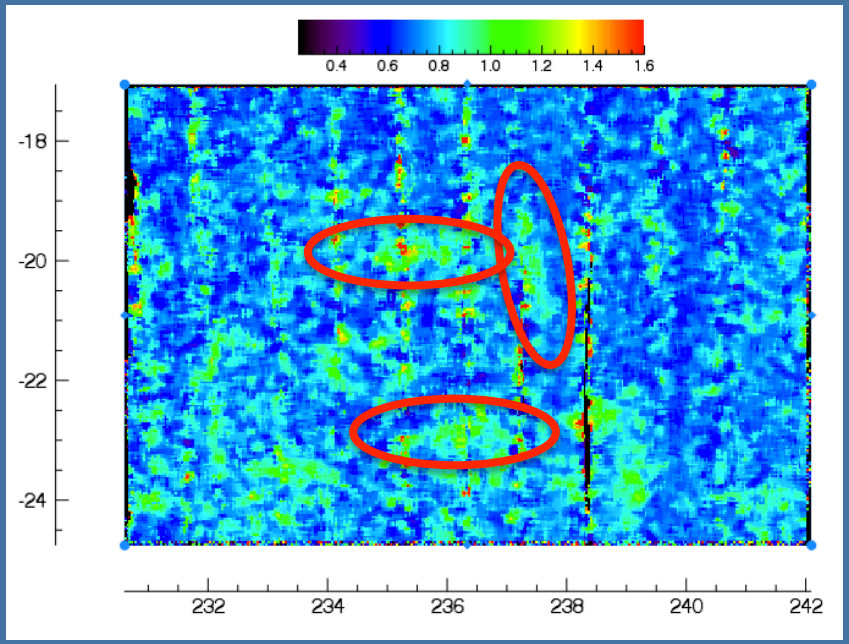


Ratio (~180-190 nm/150 nm);
with phase correction

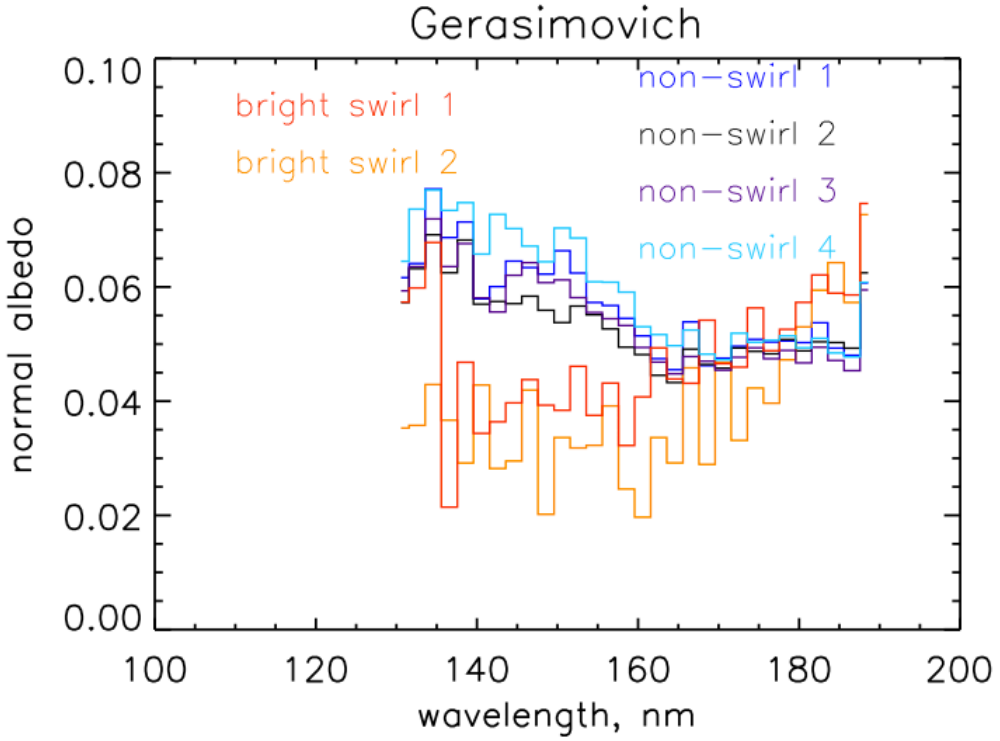
Summing 34 months of data with beta<80°

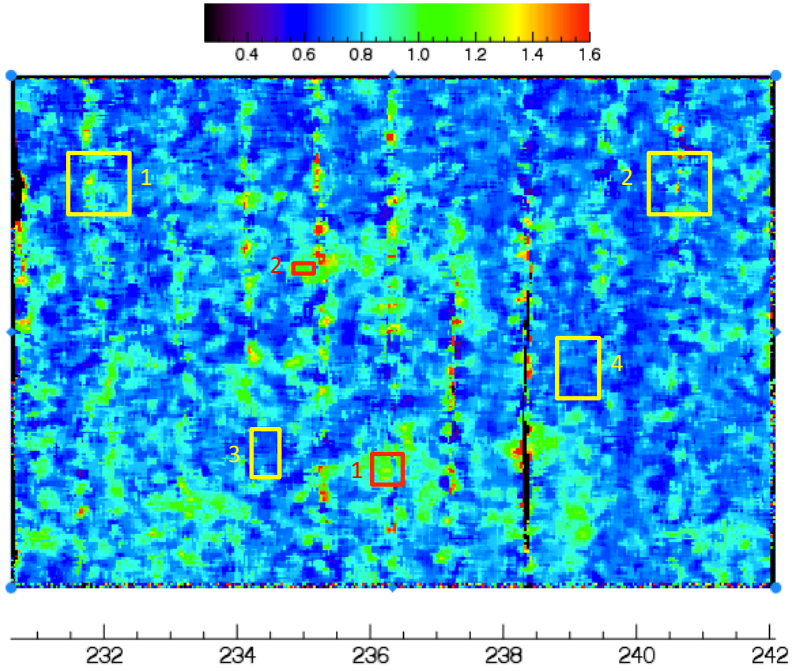
Gerasimovich swirl





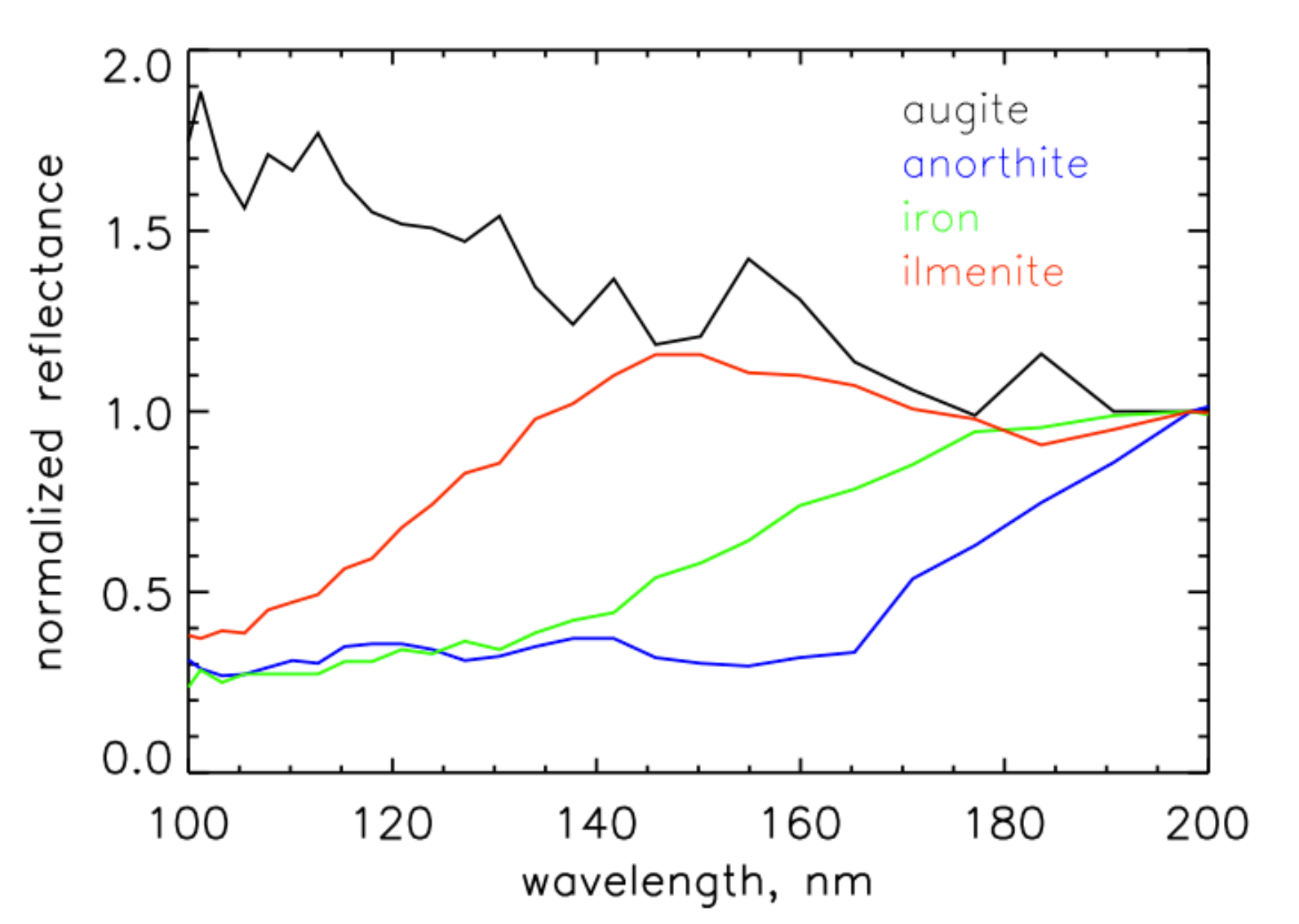
Gerasimovich swirl





The visibly-bright swirl region is significantly redder in FUV than surrounding terrain

Bluing could be due to increased pyroxene and/or ilmenite.
Gerasimovich wwirls have spectral signature similar to anorthite.



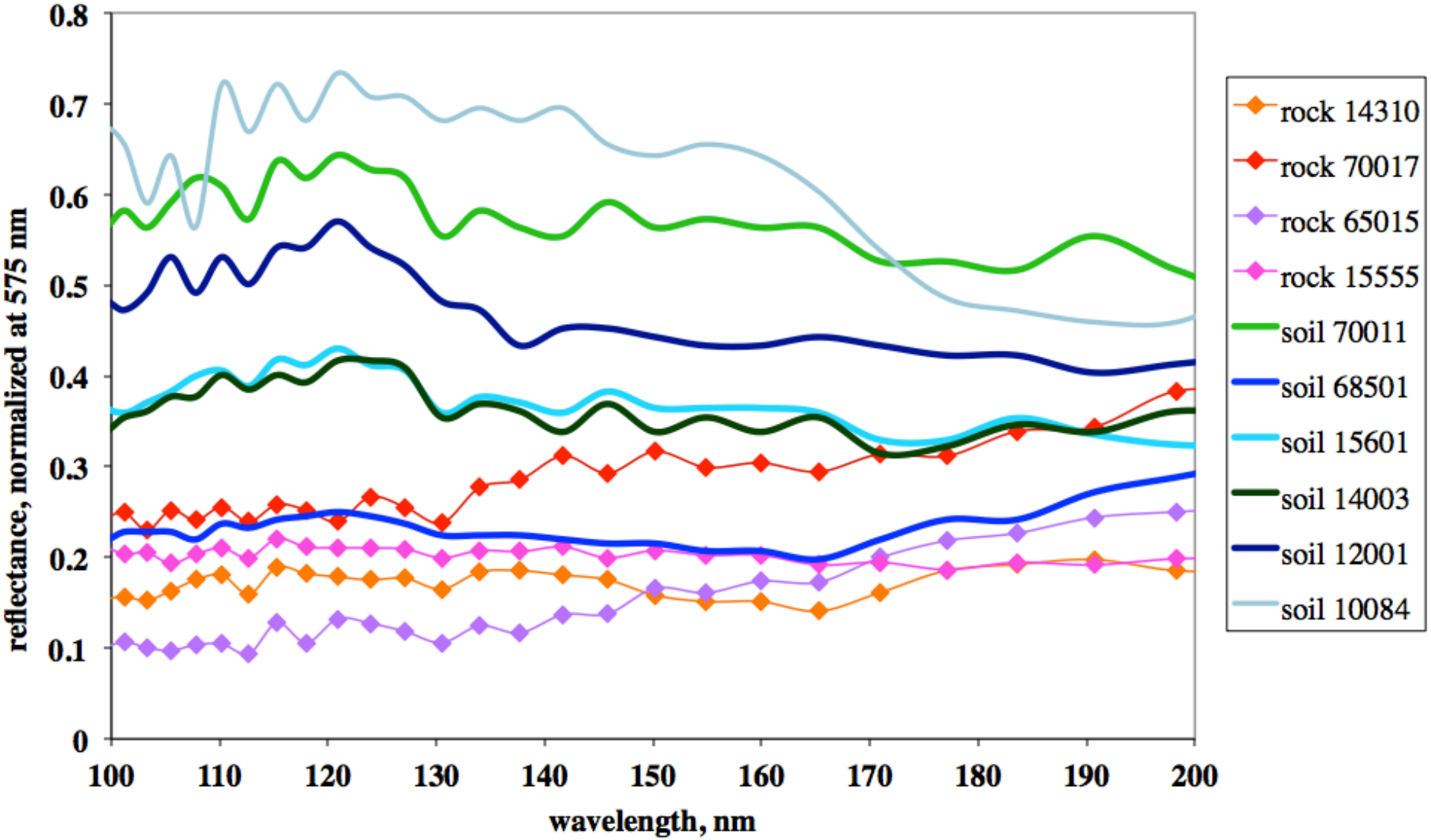
data from Wagner et al., 1987

UV Weathering Effect (#1)

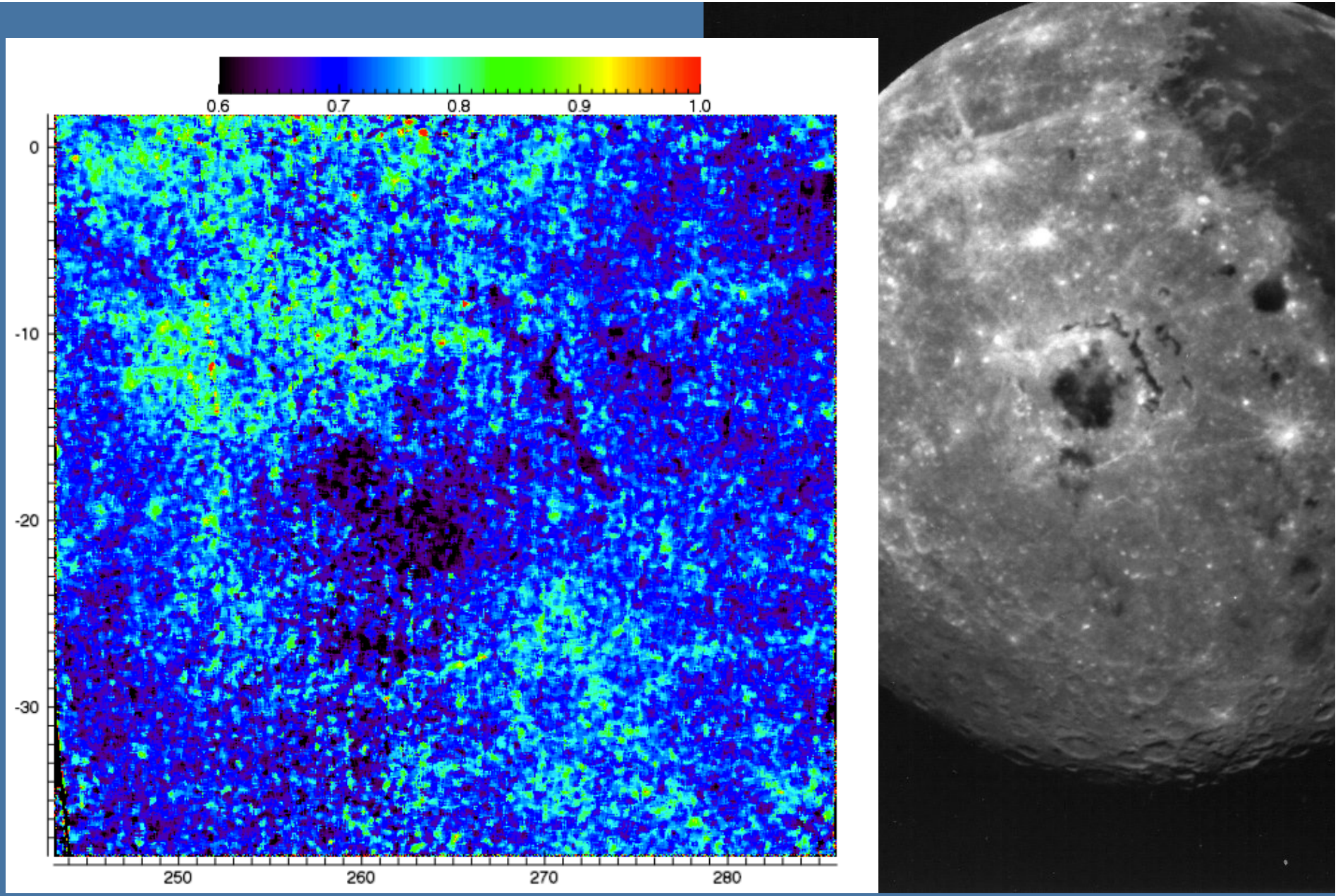
- Lunar space weathering is (**in the VNIR**) characterized by spectral reddening, darkening and degradation of absorption bands. All 3 effects are related to nanophase iron.
  - In the swirls, the normal weathering pattern is not seen – not much darkening or reddening, though absorption bands are weak.

- **In the NUV & FUV**, lunar soils are bluer than rocks (Wagner et al., 1987; Hendrix & Vilas, 2006)
  - Linking the bluing to weathering

Lunar soils: thick;
Lunar rocks: thin/diamonds

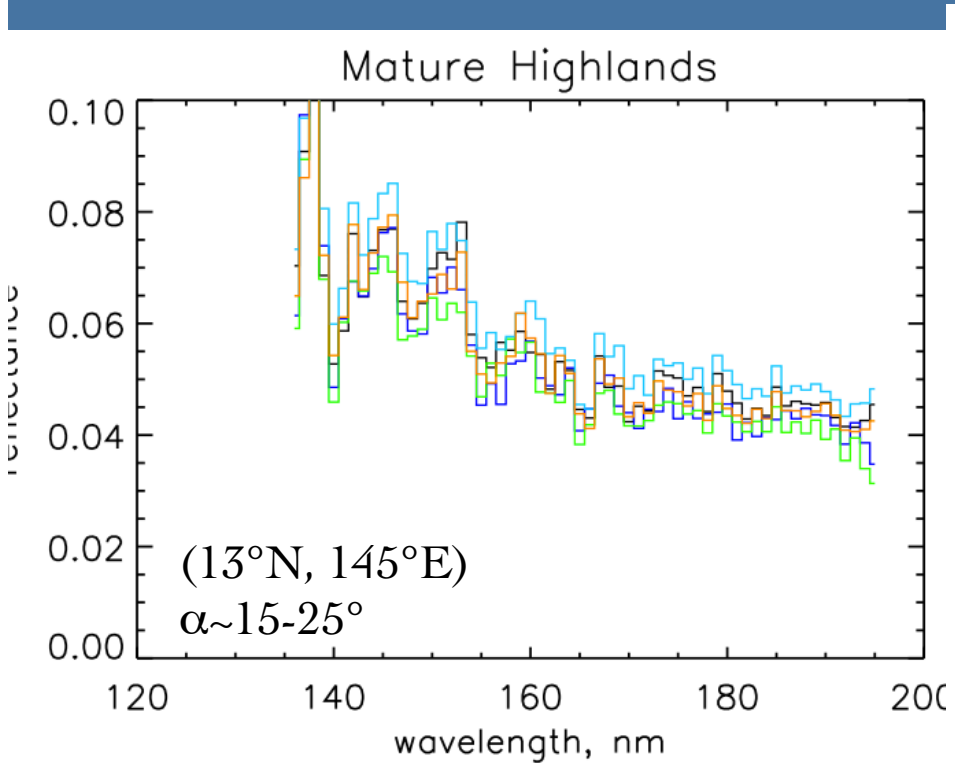


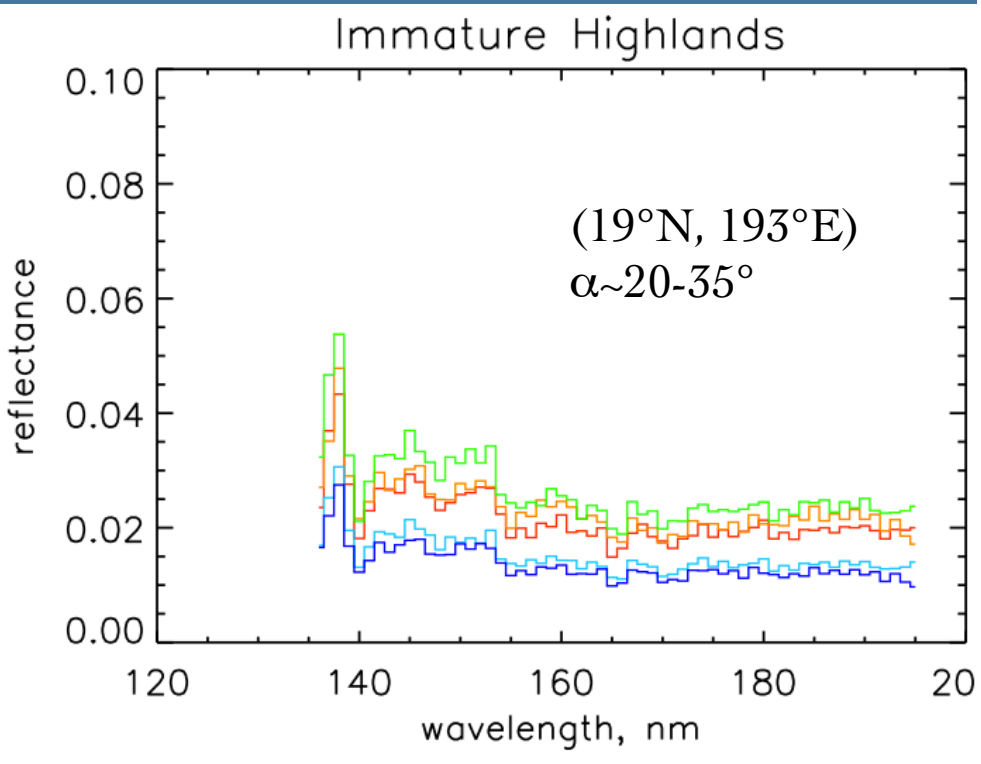
data from Wagner et al., 1987



Note that FUV ratios are <1, even for bright rays

UV Weathering Effect (#2)

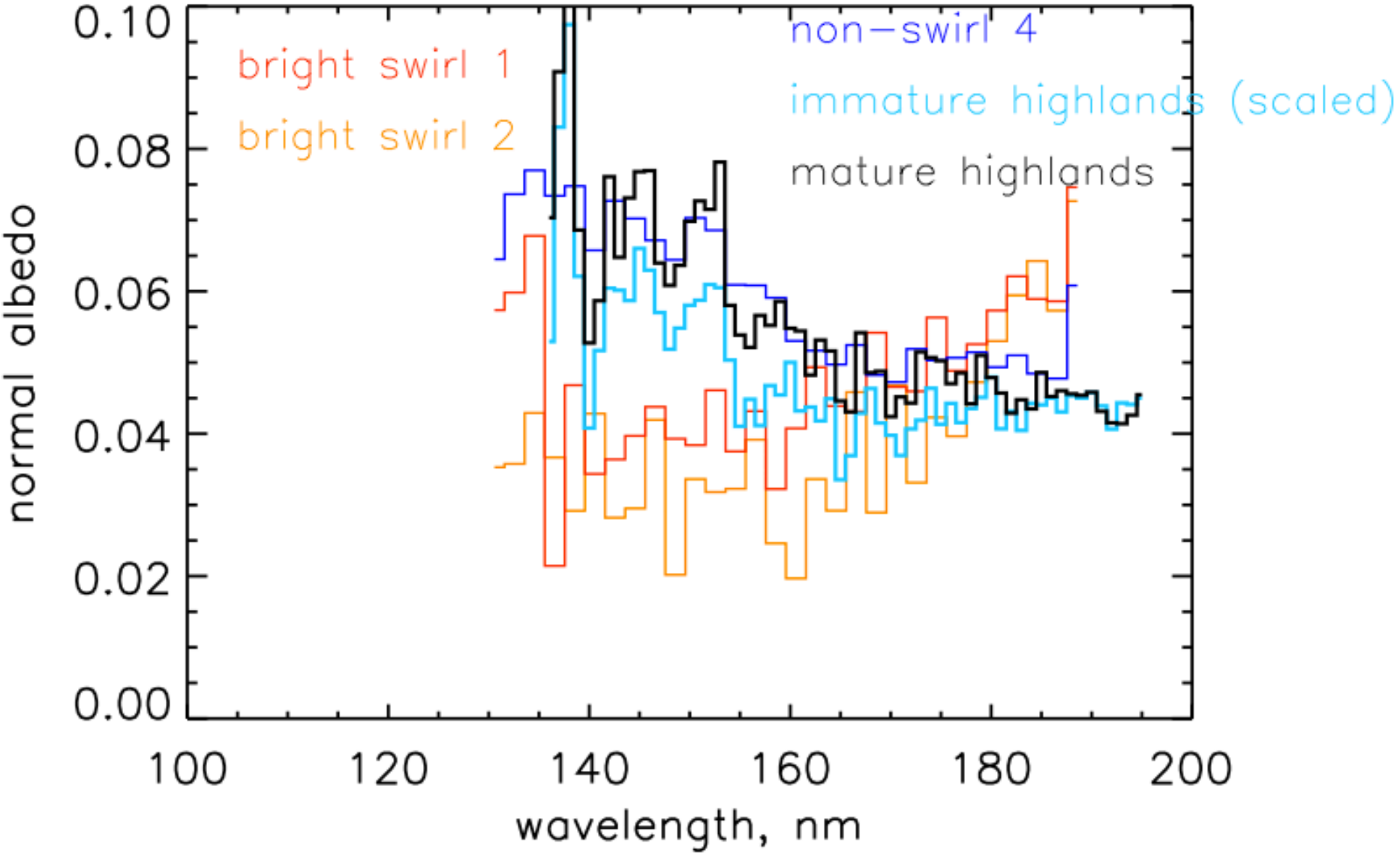




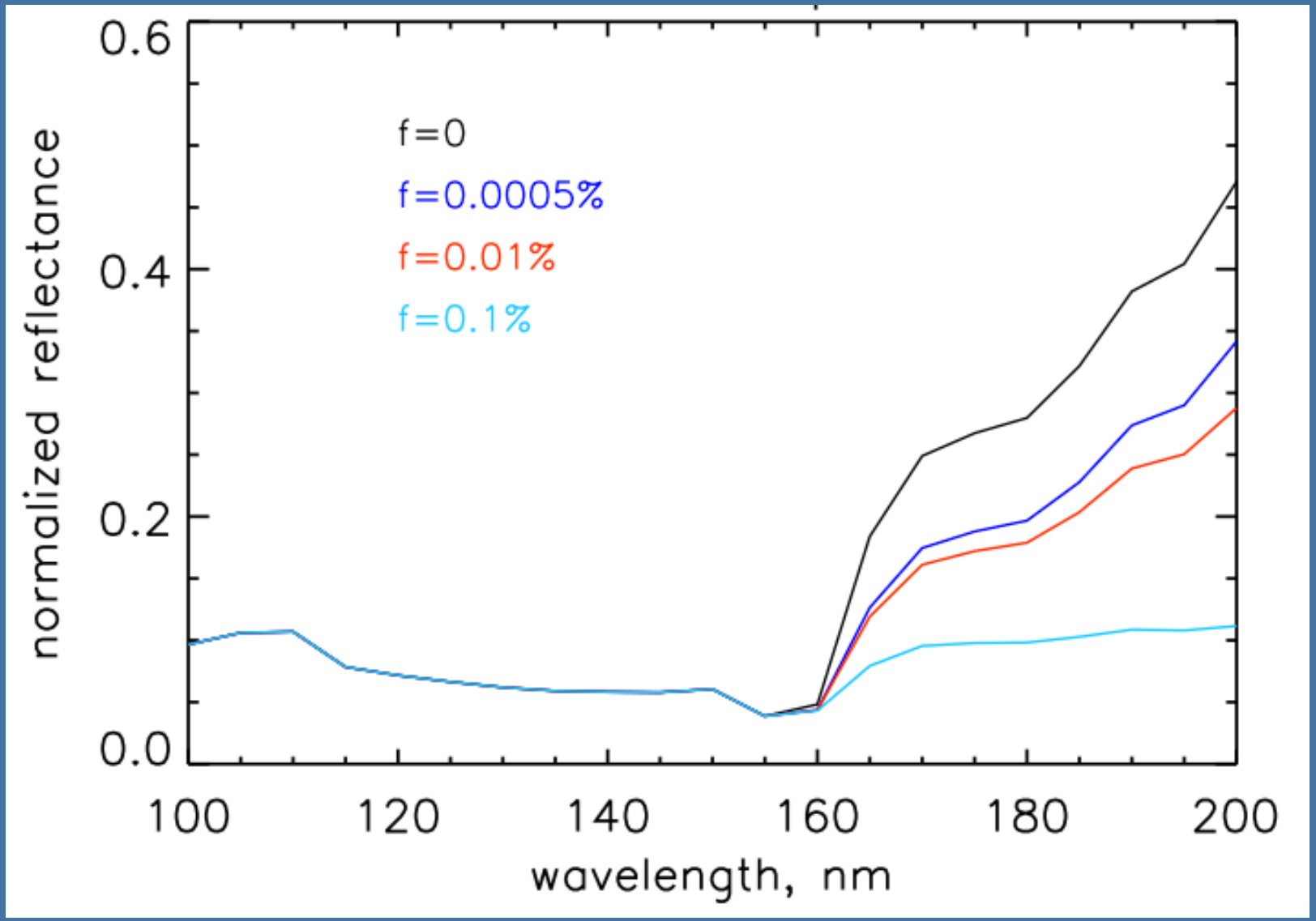
Mature regions are bluer than immature regions we also know from lunar samples.

Immature regions are darker than mature regions - attributed to a lack of SMFe and/or a lack of gardening.

Swirls are not just immature, unweathered regions.



Models of a feldspar with increasing abundances of SMFe inclusions (after Hapke, 2001).
Gerasimovich swirl is similar to a somewhat-weathered feldspar.



Summary

- Swirls are detected in LAMP FUV data
  - spectrally red compared to surrounding terrains
  - swirls are weathered to a certain extent: spectrally different from immature regions (immature soils are darker)
  - however, swirls do not show FUV spectral evidence of being mature (mature soils are blue)
- Immature soils (e.g. bright rays) are FUV dark due to a relative lack of nanophase iron (and/or a lack of gardening) and spectrally (a little) blue, likely due to pyroxene content.
- Mature soils are relatively bright due to the nanophase iron content (and/or gardening) and are bluer than immature soils, perhaps due to increased ilmenite and/or iron, especially in weather-produced grain rims
- Swirls are relatively bright like mature soils are spectrally red, not blue
  - spectrally consistent with moderately weathered feldspar
  - Consistent with the dust transport/compositional sorting model (Garrick-Bethell et al., 2011)
- Overall, we find these characteristics are consistent with a model where the magnetically anomalous swirls stand off much of the solar wind (inhibiting a bluing of the spectrum)
  - micrometeoroid bombardment acts to weather swirls
  - Gives us a clue to distinguish solar wind effects from micrometeoroid bombardment effects
  - Micrometeoroid bombardment brightens as it gardens and/or adds SMFe
  - these FUV lunar weathering effects will be described more fully in a future paper